SECTION IV. THEORY OF OPERATION

5.4.1 INTRODUCTION

This Section describes how the model H083R and 1088 hygrothermometers convert physical stimuli (temperature and dewpoint), as received from the aspirator, into usable data for transmission to the data collection package (DCP). System theory of operation for both sensors is identical and is divided into two parts. The first part describes how the ambient temperature and dewpoint temperature measurements are performed within the aspirator. The second part describes the temperature/dewpoint sensor on a detailed block diagram level. The model 1088 diagnostic circuitry is explained separately.

5.4.2 TEMPERATURE/DEWPOINT SENSOR MEASUREMENT SYSTEM CONCEPTS DESCRIPTION

The temperature/dewpoint sensor uses a temperature-controlled mirror with an imbedded heat sensor and an optical system to detect temperature dewpoint levels. The temperature dewpoint sensor system is illustrated on figure 5.4.1 and contains a thermo/mirror module; an optical system consisting of a lamp, direct sensor, and indirect sensor; and a temperature module control circuit consisting of amplifier/detectors, a summing amplifier, and power amplifiers.

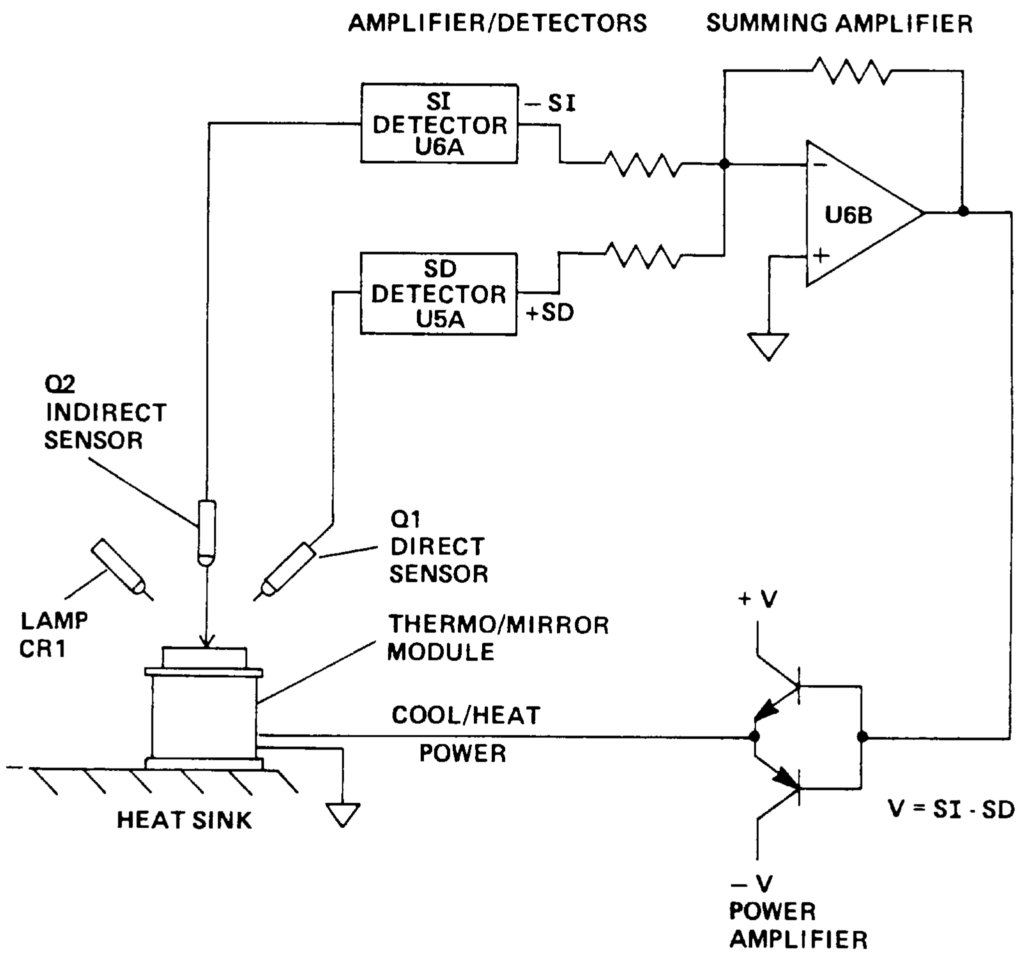

Figure 5.4.1. Dewpoint Temperature Thermal Control Loop

A light beam from a small infrared diode (CR1) is directed at the surface of a mirror at an angle of 45 degrees. Two photo transistors, Q1 and Q2, are mounted as shown to receive the reflected light. Transistor Q1, the direct sensor, is placed so that it receives a high degree of light when the mirror is clear. Transistor Q2, the indirect sensor, is placed so that it is sensitive to light that is scattered when the mirror is clouded with visible condensation. As the degree of cloudiness of the mirror surface increases, transistor Q1 tends to receive less light and Q2 tends to receive more light.

A pair of identical signal amplifier/detectors, U5A and U6A, drives a differential control amplifier, U6B. The output of this high-gain amplifier is negative when the mirror is clear and positive when the mirror is clouded because of the relative difference between the outputs of transistors Q1 and Q2.

The output of amplifier U6B, through a power amplifier, drives the mirror cooling module, U1. This device is an electronic heat pump that operates much like a thermocouple in reverse. With a dc voltage applied across the terminals, the module produces a temperature difference between its flat surfaces. Depending on the polarity of the applied voltage, the thermal module can produce a heating or cooling effect.

The feedback loop is effectively closed by the physical phenomenon of formation of condensate on the mirror as it is cooled by the thermal module. When the sensor is first turned on, the mirror is clear and transistor Q1 receives a high level of directly reflected light, and transistor Q2 receives little scattered light. This condition causes a large negative unbalance signal at the output of amplifier U6B, causing a heavy current to flow through the thermal module in the cooling direction. The unbalanced condition remains, typically for approximately 1 minute, until the mirror surface temperature has reached the dewpoint temperature. At the dewpoint temperature, the output of transistor Q1 decreases and the output of Q2 increases because of the visible effect of condensation on the mirror. The system then stabilizes at the dewpoint temperature, maintaining just enough cooling effect to keep the signal levels from transistors Q1 and Q2 in balance, with amplifier U6B and the power amplifier supplying just enough cooling current to maintain the mirror temperature at the dewpoint. If the dewpoint of the air changes or if the circuit is disturbed by noise, the loop makes the necessary corrections to restabilize at the dewpoint. The system is designed for continuous operation.

The basic operation of both the model H083R and 1088 hygrothermometers is performed by the simplified circuitry illustrated on figure 5.4.1. The remainder of the system contains the circuitry necessary to monitor the temperatures of the mirror and the ambient temperature. The system encodes that information and transmits it to the DCP. The system contains additional circuits for calibration and display of maintenance data. These circuits are described in the detailed block diagram description of the temperature/dewpoint sensor provided in paragraph 5.4.3.

5.4.3 DETAILED BLOCK DIAGRAM DESCRIPTION

5.4.3.1 **General**. The temperature/dewpoint sensor (figure 5.4.2 for H083R and 5.4.3 for 1088) makes ambient and dewpoint temperature readings, encodes the readings into a digital format, and transmits the digitally encoded measurement data to the DCP. The temperature/dewpoint sensor consists of two major assemblies: the aspirator and the transmitter.

5.4.3.2 **Aspirator 2MT4A1**. The aspirator contains two thermo resistors. One thermo resistor measures ambient temperature and the other measures dewpoint temperature. The ambient temperature resistor is mounted directly in the incoming air stream and is connected to the transmitter via a cable. The dewpoint temperature resistor is embedded in the mirror, whose temperature is electronically controlled to remain at the dewpoint. Temperature control of the mirror is performed by optical sensors and a thermoelectric heat pump. Optical sensor direct and indirect output signals are sent to the transmitter, which sends control signals via the auxiliary power supply to the thermoelectric heat pump to control the temperature of the mirror. The control signals are applied to the thermoelectric heat pump via pins P and R of connector J1. A positive voltage at pin J1-R indicates a heating condition; a negative voltage indicates a cooling condition.

5.4.3.3 **Transmitter 2MT4A2**. The transmitter contains the system power supply, control circuits, and calibration circuits. The transmitter receives the temperature data and converts the data into digital measurement data, which are transmitted to the DCP.

Calibrator Assembly MT4A2A2 routes the ambient sensor (TA) and the dewpoint sensor (TD) or special calibrator signals to the transmit logic board measurements circuits. In the model H083R, during system calibration or troubleshooting, the calibrator assembly enables the selection of one of three standard resistor values. These three values simulate temperatures of -50, 0, and +50 degrees Celsius (°C). When in the -50°C position, TA indicates -50 and TD indicates -55.5. The reason for the difference is that the dewpoint channel has been compensated to indicate dewpoint, not frost point, below 0°C. In the model 1088, during system calibration or troubleshooting, the calibrator assembly enables the selection of one of two standard resistor values. These values simulate temperatures of 0°C (32°F) and +50°C (122°F). The °F values are displayed on the monitor display (122 displayed as 22.0). In addition, the model 1088 sensor contains a calibration select circuit that enables the sensor to automatically select the calibration resistors when it runs its diagnostic test. The circuit consists of four relays that are controlled by calibration select signals, which are received from the transmit logic board. These control signals are active when the mode select switch is set to the OPR position. When a calibration check of model 1088 is performed automatically, the resulting TA and TD values are retained on the 1088 OID page.

The temperature input amplifiers receive the TA and TD sensor input signals and are configured as standard operational amplifiers. The TA and TD sensor resistive inputs serve as the feedback resistors for the amplifiers. A 6.2V reference signal is fed through 1240-ohm input resistors to the amplifiers. The output of the amplifiers depends on the ratio of the input resistors to the resistance of the TA and TD sensors. At 0°C, the sensor's resistance is 100 ohms; therefore, the output of the amplifiers is -0.5V. These signals are applied to the TA and TD scaling circuits, which offset the inputs by 0.5V such that a -0.5V input signal results in a 0V output from the scaling circuits. The gain of the scaling amplifiers is set such that a ±50°C input from the sensors results in a ±2V output signal from the scaling amplifiers. The TA0 and TD0 offset variable resistors enable the offset of the scaling circuit to be set at +0.5V. The TA+ and TD+ gain variable resistors enable the gain of the amplifiers to be set to 20. Proper adjustment of these resistors is performed during sensor calibration.

The TD/TA select logic receives the TA and TD signals from the scaling amplifiers and a temperature select signal from the temperature processing control processing unit (CPU). Based on the state of the temperature select signal, the TD/TA select logic selects either the TA or TD signal and applies it to the analog to digital (A/D) temperature converter.

The A/D temperature converter measures the TD/TA input and converts it to a 12-bit digital word, which is routed to the temperature processing CPU. The measurement cycle is started by the CPU, which issues a RUN command. During this measurement cycle, the A/D converter activates the status line with a busy signal, which remains active until the measurement cycle is completed. When the busy status is removed, the CPU activates the hold signal and reads the digitally encoded temperature data from the A/D converter. The cycle is then repeated. In addition to performing the measurement function, the A/D temperature converter also provides a 2.458 MHZ system clock signal to the measurement processing and display CPU's.

The heat pump control circuit receives the sensor direct and sensor indirect signals from the mirror/dewpoint temperature sensor circuit and sums these signals to generate heat/ cool commands for application to the auxiliary power supply. The heat pump control circuit also applies a signal to the heat limit detect circuit, which monitors the heat pump control circuit heat/cool circuitry. If either circuit fails, the heat limit detect circuit activates an error signal to the CPU, which responds by sending an error message to the DCP. The CPU also monitors the TD sensor measurement data. If this measurement indicates a TD reading of 65°C or greater, the CPU activates the cool protect command to force the heat pump control circuit into a cool condition to protect the mirror assembly. During system calibration, the heat pump control circuit is overridden by heat/cool switch S2 on the model H083R or the mode switch on the model 1088. Overriding the heat pump control circuit in this manner illuminates one of the heat limit indicators on the transmit logic board. This is a normal condition due to the 12V drive signal being applied to pin 5 during calibration.

The auxiliary power supply provides the heat/cool current to the thermoelectric heat pump, ac lamp voltage to the LED in the mirror/dewpoint temperature sensor circuit, and ±12V power to the autobalance module and transmit logic board. Two types of auxiliary power supplies are used in the temperature/dewpoint sensor. Although the power supplies perform the same functions and are interchangeable, the circuitry used to generate the ±12V outputs is different. The part numbers of these two supplies are the only way to distinguish between the two. The heat/cool current to the thermoelectric heat pump is controlled by the heat/cool command from the heat pump control circuit. When the heat/cool command is positive, the auxiliary power supply outputs a pulsating positive dc signal to the thermoelectric heat pump. When the heat/cool command is negative, the auxiliary power supply outputs a negative cool signal to the thermoelectric heat pump. Auxiliary power supply P/N 1063-2031 generates the ±12V outputs by utilizing an internal oscillator, which is driven by the +5V input from the +5 volt power supply. Auxiliary power supply P/N 1063-06B generates the ±12V output by utilizing a full wave rectifier, which is powered by the 115 vac input.

The maintenance display circuit consists of a display CPU, display select switch S1, display switch S2 (model 1088 only), a polarity indicator, and a 3-digit display. The display CPU receives the serial temperature data from the temperature processing CPU. The display CPU converts the data into the proper format to drive the 3-digit display. The display select switch enables either TD or TA temperature data to be displayed by routing the respective data strobe to the 3-digit display. For model 1088, display switch S2 must be pressed in order to display TA or TD as selected by display select switch S1. As shown on sheet 2 of figure 5.4.3, pressing display switch S2 also opens the path of serial data to the DCP. This may cause the DCP to miss responses to data requests. As such, the DCP CST may register transmission errors for the SIO port corresponding to the model 1088 sensor. This is a normal occurrence when display switch S2 is pressed and should not be considered as an actual sensor failure.

The temperature processing CPU controls measurement of the TA and TD data, transmits the TA and TD data to the display CPU and DCP, monitors the heat pump control circuit, and activates the autobalance circuit.

The autobalance module cancels the effects of contaminations on the mirror by applying a fixed dc offset voltage to the heat pump control circuit. The dc offset voltage cancels the indirect sensor error signal being received from the mirror/dewpoint temperature sensor circuit. The autobalance circuit is activated once every 24 hours by the temperature processing CPU. The balance cycle is initiated by the CPU, which activates the heat command signal that is applied to the heat pump control circuit, forcing the circuit into a heat mirror cycle. The heat command signal remains active for 5 minutes to ensure that all moisture has been driven off the mirror. The CPU then enables the balance enable signal, which in turn activates the autobalance circuit. If the mirror is dirty, the heat/cool signal remains in a heating state because the sensor circuit is still trying to clear the mirror. This positive signal is applied to the motor control circuit, which in turn generates a balance offset dc voltage. This voltage is applied back to the heat pump control circuit. The enable signal remains active for 15 seconds, which is adequate time for the autobalance circuit to stabilize. At the end of the cycle, the balance offset signal remains fixed and acts as an offset value to cancel the effects of the indirect sensor signal trying to drive the thermoelectric heat pump into a heat condition. Each time the autobalance circuit is activated, it attempts to eliminate the effects of contaminations on the mirror by repeating this cycle. During maintenance, after the mirror is cleaned, the technician must physically reset the autobalance circuit by returning the autobalance bias resistor to its zero position.

The model 1088 sensor diagnostic circuitry (figure 5.4.3) consists of a critical voltage monitoring circuit, a fan fail monitoring circuit, a dirty mirror monitoring circuit, and remote select logic circuitry. The model 1088 critical voltage monitoring circuit uses comparator circuitry to monitor the outputs from the +5 volt power supply and the auxiliary power supply. The critical voltage monitoring circuit receives +12V, -12V, +5V, and -5V values and compares the sum of these voltages to a fixed reference voltage. If any of the voltages falls below a predefined value, the comparator generates a critical voltage error signal, which is monitored by the temperature processing CPU.

The model 1088 fan fail monitoring circuit uses a comparator circuit to monitor the values of two thermal resistors located in the aspirator. Only one of these resistors is located in the airflow of the fan. The cooling effect of the airflow creates a resistive difference between the two resistors. The comparator monitors these resistive values. If the two values become equal, the fan fail monitoring circuit generates a fail signal and applies it to the temperature processing CPU.

The model 1088 dirty mirror monitoring circuit monitors the balance offset signal at pin 5 of the transmit logic board. When this signal exceeds approximately 0.5V, the dirty mirror monitoring circuit activates the dirty mirror signal and applies it to the temperature processing CPU. The 0.5V balance offset signal is reached when the value on the autobalance dial is between 450 and 550.

The model 1088 remote select logic circuitry enables the temperature processing CPU to select the TEST 0, TEST 50, and SENSOR TEST functions during the automatic diagnostic. The CPU activates one of the relay control signals, which applies a 5V drive signal to the respective select relay on the calibrator assembly. The CPU monitors the position of the calibrate switch via the op mode error signal, which is applied from the calibrator assembly to pin 7 on the transmit logic board. During normal system operation, the op mode error signal should be at a logic 0, indicating that the calibrate switch is set to the OPR position.

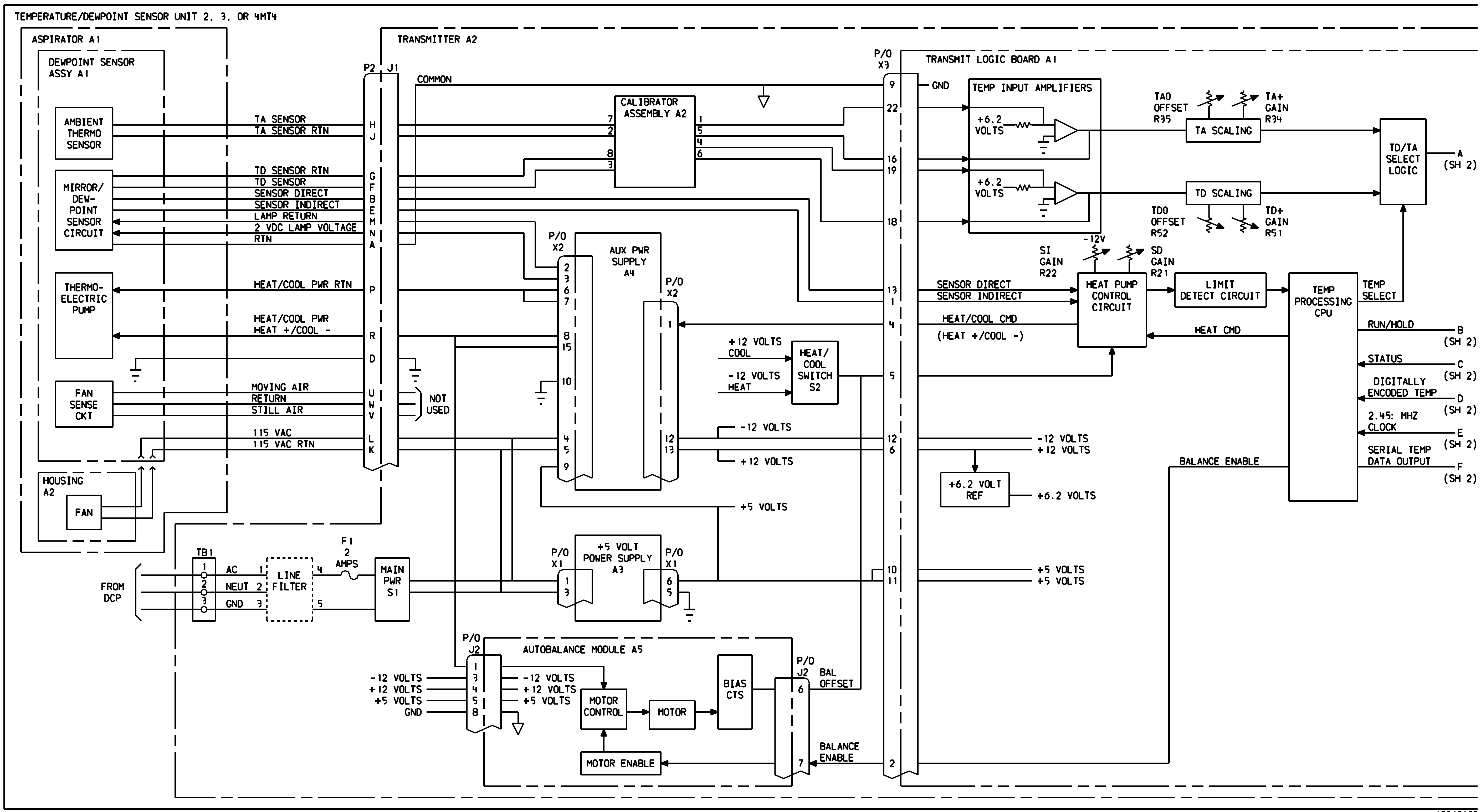

Figure 5.4.2. H083R Temperature/Dewpoint Sensor Detailed Block Diagram (Sheet 1 of 2)

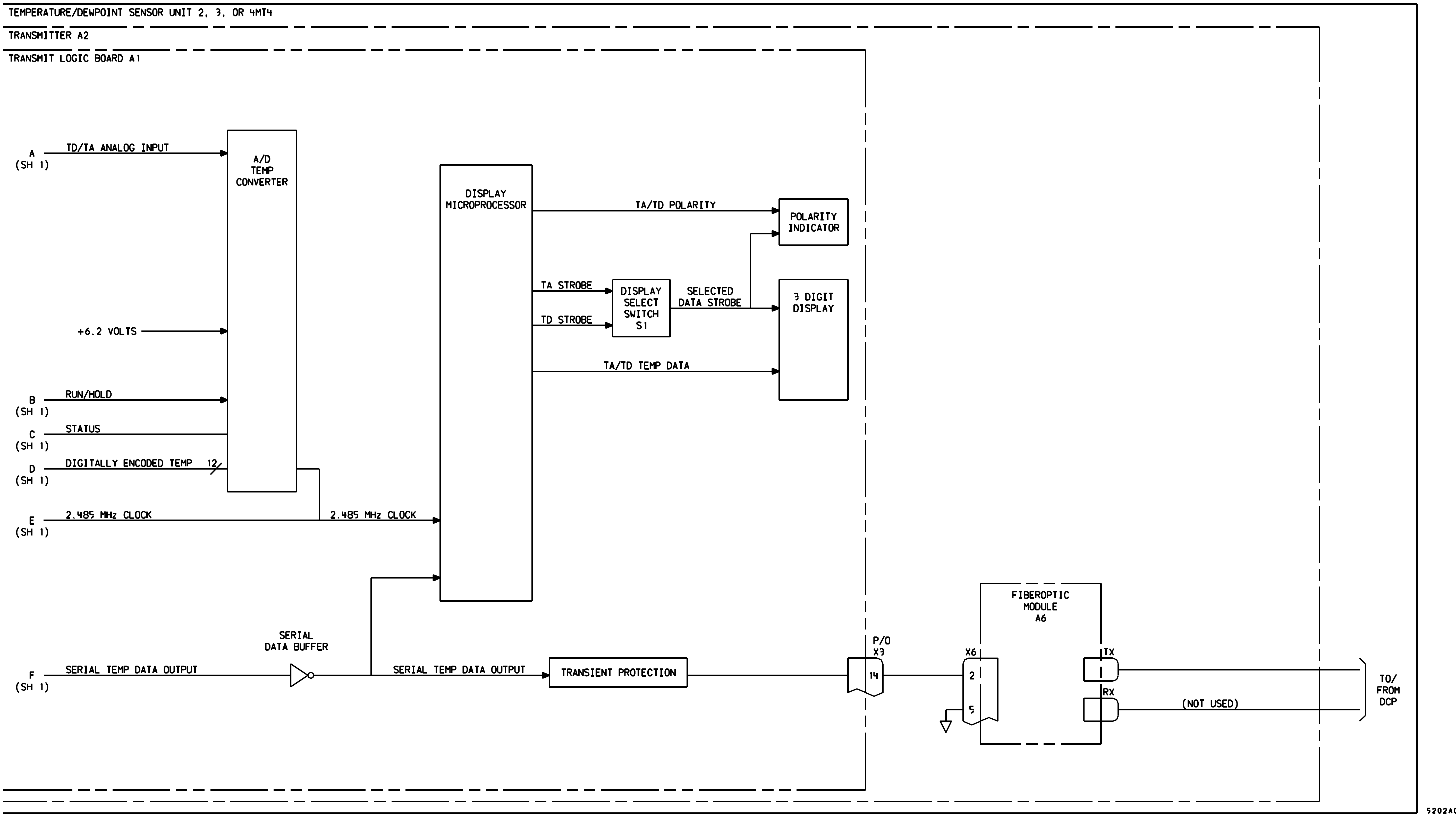

Figure 5.4.2. H083R Temperature/Dewpoint Sensor Detailed Block Diagram (Sheet 2)

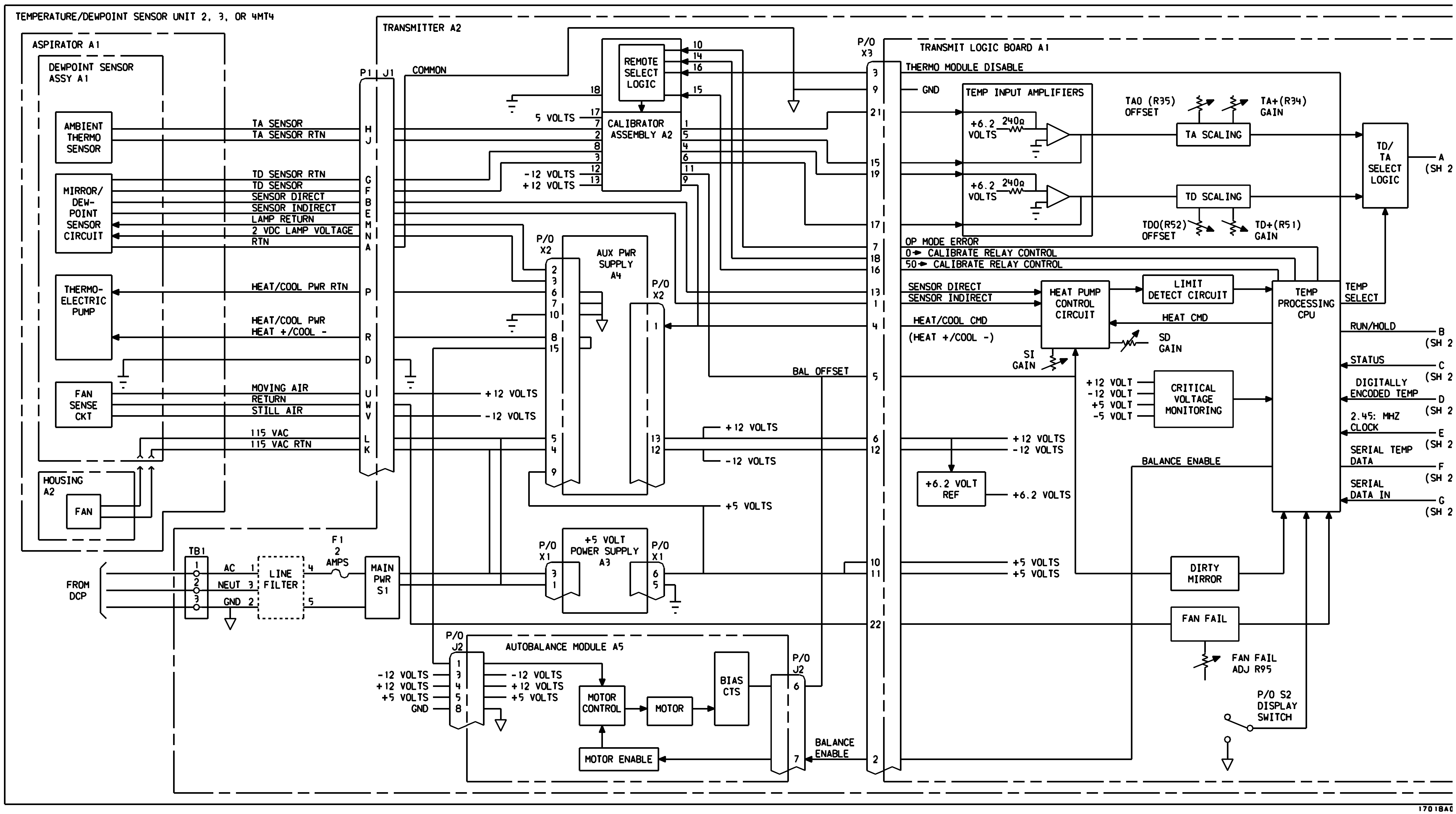

Figure 5.4.3. 1088 Temperature/Dewpoint Sensor Detailed Block Diagram (Sheet 1 of 2)

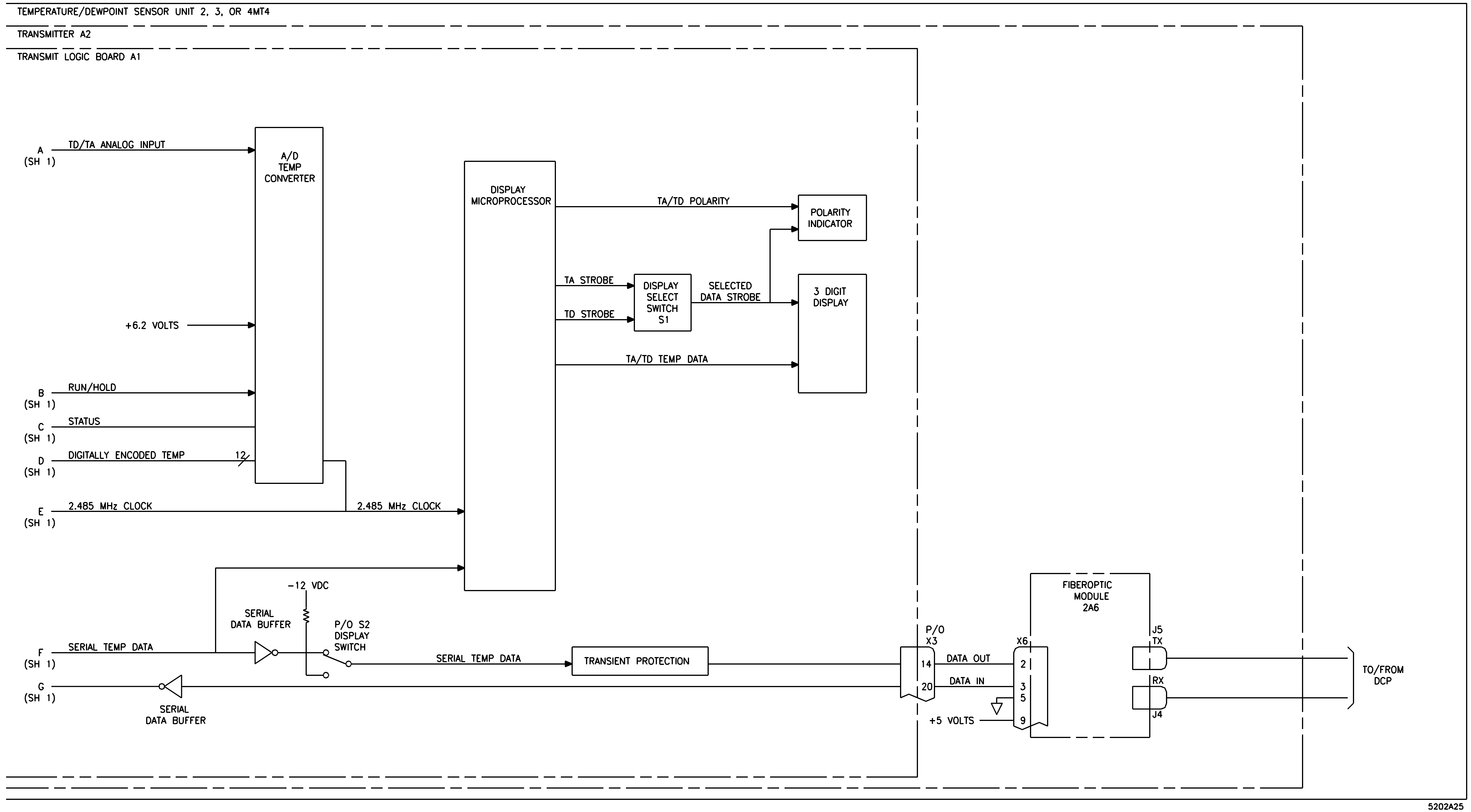

Figure 5.4.3. 1088 Temperature/Dewpoint Sensor Detailed Block Diagram (Sheet 2)